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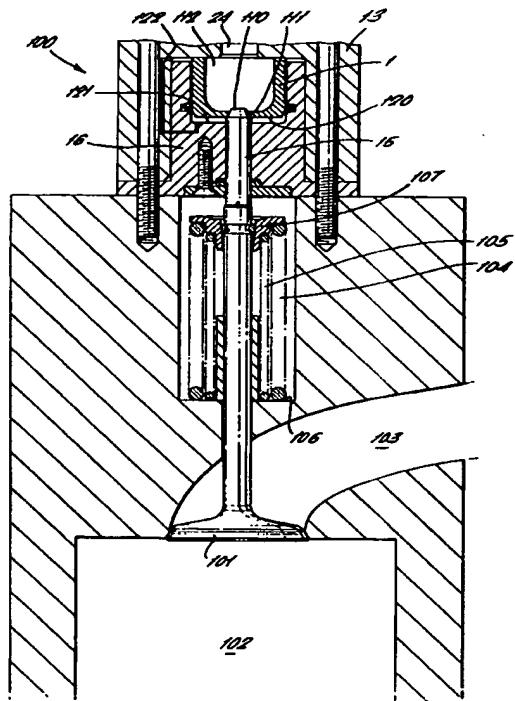
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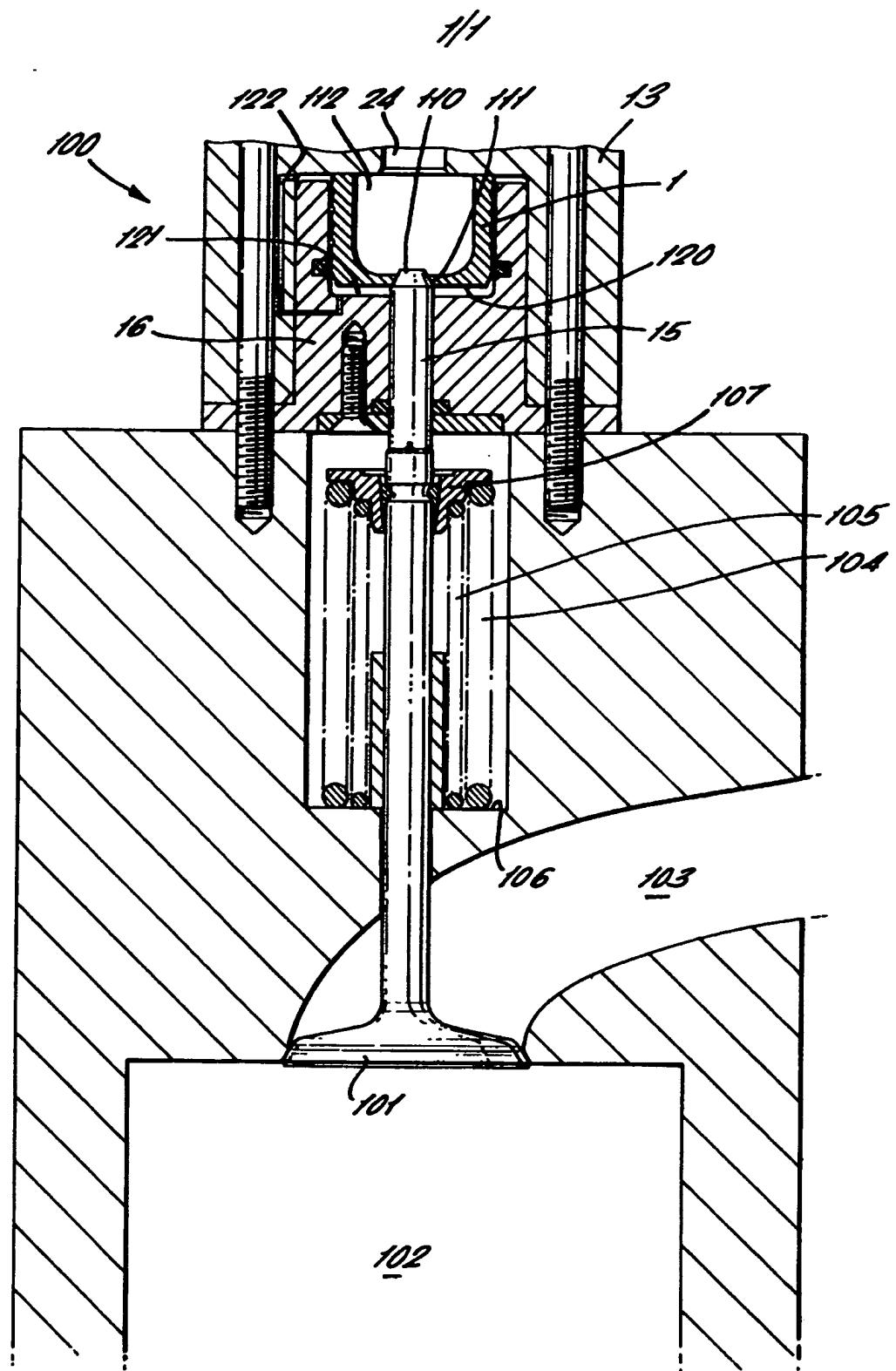
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JP 600085209 A JP 2000282823 A  
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(54) Abstract Title: Arrangement of an i.c. engine poppet valve and hydraulic actuator

(57) The arrangement comprises a housing (16), spring means (104,105) for biasing the poppet valve 101, eg an exhaust valve, into engagement with its valve seat, a first piston 1 of a first cross-sectional area slidably in a first chamber formed in the housing 16, the first piston 1 having a passage 111 therethrough for the flow of hydraulic fluid, and a second piston 15 of smaller cross-sectional area slidably in a second chamber also formed in the housing 16. The second piston 15 has an upper surface 110 engageable by a lower surface of the first piston 1. The second chamber opens on to the first chamber which is connectable to pressurised hydraulic fluid supply and return lines. The passage 111 in the first piston 1 does not both (a) align with the second piston 15 and (b) have a portion of constant cross-sectional area greater than the cross-sectional area of the second piston 15. The actuator applies a large force for the first part of the valve motion after which the amount of fluid required for each millimetre of valve motion is much reduced because of the reduction in effective cross-section.





An Arrangement of an Internal Combustion  
Engine Poppet Valve and an  
Actuator therefor

5        The present invention relates to an arrangement of an internal combustion engine poppet valve and an actuator therefor.

10      The majority of internal combustion engines have poppet valves as inlet and exhaust valves controlling flow of air into the combustion chambers of the combustion engines and flow of combusted gases to exhaust. Conventionally, the poppet valves have been operated by cams on rotating camshafts. More recently, 15      poppet valves have been operated by hydraulic actuators. In large diesel engines residual pressure in the combustion chambers can be 70 bar when the exhaust valves are opened. This requires considerable force to be applied on the exhaust valves.

20      The present invention provides an arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor comprising:

25      an actuator housing;  
          spring means for biassing the poppet valve into engagement with a valve seat therefor;  
          a first piston of a first cross-sectional area slidable in a first chamber in the actuator housing, the first piston having a passage therethrough; and  
30      a second piston of a second cross-sectional area smaller than the first cross-sectional area slidable in a second chamber in the actuator housing; wherein:  
          the first chamber is connectable to a pressurised hydraulic fluid supply line and to a hydraulic fluid return line; and

in order to open the poppet valve: the first chamber is connected to the pressurised hydraulic fluid supply line and then supplied pressurised hydraulic fluid acts initially on the first piston to give rise to a first magnitude force which is initially relayed via the second piston to the engine valve to open the valve; initially the first piston, the second piston and the engine valve all move together under the action of the first magnitude force until the first piston reaches an end stop; and thereafter the supplied pressurised hydraulic fluid flows from the first chamber through the passage in the first piston to act on the second piston and to thereby give rise to a second smaller magnitude force under the action of which the second piston and the valve move together until the valve is fully open; and in order to close the previously opened poppet valve: the first chamber is connected to the hydraulic fluid return line and then the biassing force applied by the spring means to the valve forces the valve to move back towards its valve seat; initially the valve and the second piston move together with the second piston expelling fluid from the second chamber via the passage in the first piston to the hydraulic fluid return line until the second piston engages the first piston; and thereafter the first piston, the second piston and the valve all move together under the biassing force applied by the spring means with the first piston expelling hydraulic fluid from the first chamber to the hydraulic fluid return line until the poppet valve engages the valve seat therefor.

The actuator applies a large force on e.g. an exhaust valve for the first part of the engine valve motion, after which the pressure in the combustion chamber has decayed and the actuator need not apply

such a large force. Thereafter, the amount of fluid required for each millimetre of valve motion is much reduced because the operative cross-sectional area of the actuator is much less than in the first part of  
5 the valve stroke.

A preferred embodiment of internal combustion engine valve actuator will now be described with reference to the accompanying figure which is a cross-  
10 sectional view of the actuator.

In the figure there can be seen an actuator 100, which operates a poppet valve 101 which serves as an exhaust valve controlling flow of combusted gases from  
15 a cylinder 102 to an exhaust passage 103. The valve 101 is biassed by a pair of concentric valve springs 104,105 which act between a spring seat surface 106 and a collar 107 secured to the top of the poppet valve 101. The top of the poppet valve 101 is engaged  
20 by a small piston 15 slidable in a first bore in an inner actuator housing 16. The top of the small piston 15 is engageable by a large piston 1 slidable in a second bore in the inner actuator housing 16 aligned with the first bore. The actuator 100 has an  
25 outer actuator housing 13 which surrounds the inner actuator housing 16.

Extending through the outer actuator housing 13 is a passage 24 for flow of hydraulic fluid. A valve  
30 (not shown) will be used to control flow of hydraulic fluid through the passage 24 to and from the actuator 100.

As shown in the figure the valve 101 is biassed  
35 into its valve seat by the springs 104,105. A frusto-

conical top portion 110 of the piston 15 is engaged in a socket of matching shape and configuration in the lower surface of the piston 1. A fluid passage 111 opens onto the socket to allow fluid flow across the 5 piston 1. As shown in the Figure, the valve springs 104,105 have biassed piston 15 into engagement with the piston 1 and biassed both pistons 1, 15 into their uppermost positions.

10        If the poppet valve 101 is an exhaust valve in a large capacity diesel engine then the pressure in the cylinder 102 can be as high as 70 bar when the actuator 100 first opens the valve 101. In order to apply a force on the valve 101 sufficient to open the 15 valve the piston 1 is provided in the actuator. When pressurised fluid is introduced into the chamber 112 defined between the piston 1 and the outer actuator housing 13 then the fluid acts to slide the piston 1 downwardly in the inner housing 16. The force applied 20 to the valve 101 is the product of pressure of the pressurised fluid and the area of the piston 1.

25        The piston 1 is slid down in the bore in the inner housing 16 until it abuts the end of the bore in the inner housing 16 in which it slides. Thereafter, the pressurised fluid acts to move the piston 15 relative to the first piston 1, the piston 15 sliding in the inner housing 16, with hydraulic fluid flowing through the aperture 111 in piston 1. Therefore the 30 first part of the opening motion of the valve 101 is occasioned by motion of the pistons 1 and 15 together and thereafter the opening motion of the valve 101 is occasioned by the motion of the smaller piston 15 only.

The force applied by the piston 15 on the valve 101 is the product of the pressure of the fluid and the cross-sectional area of the piston 15. Since the cross-sectional area of piston 15 is much less than 5 the cross-sectional area of piston 1 the force applied by the piston 15 on valve 101 is much less than the force applied by piston 1. On the other hand, when the valve 101 is moved under control of piston 1 then the amount of fluid needed for each millimetre of motion 10 is the product of the distance travelled and the cross-sectional area of piston 1, whereas when the valve 101 moves under the control of piston 15 the volume of fluid for each millimetre of motion is the product of the distance travelled and the much smaller 15 cross-section of the piston 15. The power required of a hydraulic pump pressuring the fluid supplied to the actuator is proportional to the rate of flow of fluid and thus reducing the amount of fluid needed for each millimetre of valve motion is an energy saving 20 measure.

The pressure in the cylinder 102 quickly decays to atmosphere once the valve 101 is opened. Thus the actuator can easily move the valve 101 with the lower 25 force applied by piston 15.

To prevent a build up of fluid between the lower face 120 of the piston 1 and the opposing face 121 of the chamber in which the piston 1 moves, leakage of 30 fluid past the cylindrical outer surface of the piston 1 is permitted. Also a small passage 122 allows fluid to flow from between the faces 120,121 to the upper side of the piston 1 as the piston 1 moves downwardly. The fluid trapped between the faces 120,121 will have 35 the beneficial effect of acting as a cushion for the

piston 1 to prevent the piston 1 impacting the face 121 with the consequent problems of noise and wear.

When the valve 101 is to be returned to its valve seat the chamber 112 is connected via passage 24 to a fluid return and then the valve springs 104,105 force the valve 101 and the piston 15 upwardly with fluid expelled from between the pistons 1 and 15 through the orifice 111 in the piston 1 to the passage 24. As the piston 15 moves upwardly the frusto-conical top of the piston 15 engages with and locates in the conical recess in the lower surface of piston 1, with the co-operating conical surfaces acting to centre the piston relative to the piston 1. Also as the facing surfaces of the frusto-conical top 110 of the piston 15 and the aperture 111 draw close to one another then the aperture defined therebetween narrows and thus the flow of fluid therethrough is restricted. This has a beneficial damping effect on the portion of the piston 15 which serves to soften the impact as the piston 15 comes into abutment with the piston 1. Once the piston 1 fully engages piston 15 then the two pistons 1 and 15 move together under the action of the springs 104 and 105 until the valve 101 is returned to its valve seat.

Ideally, the transverse cross-section diameter of the piston 15 is chosen to be approximately the same as the transverse cross-section of the stem of valve 101 and the transverse cross-section diameter of the piston 1 is chosen to be approximately the same as the maximum diameter of the valve head of the valve 101. The diameter of the piston 1 will be chosen to be as small as possible given that for a set pressure of supplied hydraulic fluid a certain force must be achievable to overcome residual pressure in the chamber 102. Also the diameter of the piston 15 is

chosen to be as small as possible given that the piston, with a set pressure of supplied by hydraulic fluid, must be able to apply a force sufficient to overcome the biassing forces of the springs 104, 105 5 throughout travel of fine valve 107.

The engine valve 101 will typically have a total stroke of 15 mm of which only the initial 1 to 1.5 mm will be occasioned by motion of the large piston 1 and 10 the remainder of which will be occasioned by the smaller piston 15.

CLAIMS

1. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor comprising:
  - 5 an actuator housing;
  - spring means for biassing the poppet valve into engagement with a valve seat therefor;
  - 10 a first piston of a first cross-sectional area slidable in a first chamber in the actuator housing, the first piston having a passage therethrough; and
  - 15 a second piston of a second cross-sectional area smaller than the first cross-sectional area slidable in a second chamber in the actuator housing; wherein:
    - the first chamber is connectable to a pressurised hydraulic fluid supply line and to a hydraulic fluid return line; and
    - 20 in order to open the poppet valve: the first chamber is connected to the pressurised hydraulic fluid supply line and then supplied pressurised hydraulic fluid acts initially on the first piston to give rise to a first magnitude force which is initially relayed via the second piston to the engine valve to open the valve; initially the first piston, the second piston and the engine valve all move together under the action of the first magnitude force until the first piston reaches an end stop; and thereafter the supplied pressurised hydraulic fluid flows from the first chamber through the passage in the first piston to act on the second piston and to thereby give rise to a second smaller magnitude force under the action of which the second piston and the valve move together until the valve is fully open; and
    - 25 in order to close the previously opened poppet valve: the first chamber is connected to the hydraulic

fluid return line and then the biassing force applied by the spring means to the valve forces the valve to move back towards its valve seat; initially the valve and the second piston move together with the second

5 piston expelling fluid from the second chamber via the passage in the first piston to the hydraulic fluid return line until the second piston engages the first piston; and thereafter the first piston, the second piston and the valve all move together under the

10 biassing force applied by the spring means with the first piston expelling hydraulic fluid from the first chamber to the hydraulic fluid return line until the poppet valve engages the valve seat therefor.

15 2. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor as claimed in claim 1 wherein the second piston directly abuts the top of a valve stem of the poppet valve.

20 3. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor as claimed in claim 1 or claim 2 wherein the first and second pistons directly abut each other when moving together.

25 4. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator as claimed in any one of the preceding claims wherein the first chamber is formed in the actuator housing by a first diameter drilling and the second chamber is formed in the actuator housing by a second diameter drilling aligned with the first diameter drilling, the second diameter drilling opening on to the first diameter drilling.

30 5. An arrangement of an internal combustion engine

5       poppet valve and an actuator therefor as claimed in  
any one of the preceding claims wherein: the first  
piston has a surface facing the second piston and the  
passage through the first piston has an opening on to  
10      said surface, the said opening being at least  
partially defined by a conical abutment surface; and  
wherein the facing surface of the second piston has a  
matching conical abutment surface and the matched  
conical surfaces abut each other whilst the first and  
15      second pistons move together and by abutment seal the  
passage through the first piston.

6.      An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
15      claim 5 wherein the matched conical surfaces together  
act to restrict flow of fluid through the passage in  
the first piston as the second piston comes into  
abutment with the first piston and thereby soften  
abutment of the first and second pistons.

20     7.      An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
any one of the preceding claims comprising a passage  
through the actuator through which hydraulic fluid  
25      trapped between one side of first piston and the  
surface of the first chamber as the first piston  
approaches the end stop therefor can be relayed to the  
first chamber on the other side of the first piston.

30     8.      An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
any one of the preceding claims wherein the spring  
means comprises one or more valve springs acting  
between a collar attached to the poppet valve and a  
35      surface provided on the engine cylinder head.

9. An arrangement of an internal combustion engine poppet valve and an actuator therefor substantially as hereinbefore described with reference to and as shown in the accompanying drawing.

**Amendments to the claims have been filed as follows****CLAIMS**

1. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor comprising:
  - 5 an actuator housing;
  - spring means for biassing the poppet valve into engagement with a valve seat therefor;
  - 10 a first piston of a first cross-sectional area slidable in a first chamber formed in the actuator housing, the first piston having a passage therethrough for the flow of hydraulic fluid; and
  - 15 a second piston of a second cross-sectional area smaller than the first cross-sectional area slidable in a second chamber formed in the actuator housing, the second chamber opening on to the first chamber; wherein:
  - 20 the first chamber is connectable to a pressurised hydraulic fluid supply line and to a hydraulic fluid return line; and
  - the second piston has an upper surface engageable by a lower surface of the first piston; and
  - 25 the first piston is configured without a passage which is both aligned with the second piston and which has a portion of constant cross-sectional area greater than the said second cross-sectional area;
  - in order to open the poppet valve: the first chamber is connected to the pressurised hydraulic fluid supply line and then supplied pressurised
  - 30 hydraulic fluid acts initially on the first piston to give rise to a first magnitude force which is initially relayed via the second piston to the engine valve to open the valve; initially the first piston,

the second piston and the engine valve all move together under the action of the first magnitude force  
5 until the first piston reaches an end stop; and thereafter the supplied pressurised hydraulic fluid flows from the first chamber through the passage in the first piston to act on the second piston and to thereby give rise to a second smaller magnitude force  
10 under the action of which the second piston and the valve move together until the valve is fully open; and

in order to close the previously opened poppet valve: the first chamber is connected to the hydraulic fluid return line and then the biassing force applied  
15 by the spring means to the valve forces the valve to move back towards its valve seat; initially the valve and the second piston move together with the second piston expelling fluid from the second chamber via the passage in the first piston to the hydraulic fluid  
20 return line until the second piston engages the first piston; and thereafter the first piston, the second piston and the valve all move together under the biassing force applied by the spring means with the first piston expelling hydraulic fluid from the first  
25 chamber to the hydraulic fluid return line until the poppet valve engages the valve seat therefor; and

the movement of the second piston relative to the first piston is limited by abutment of the upper surface of the second piston with the lower surface of  
30 the first piston.

2. An arrangement of an internal combustion engine poppet valve and a hydraulic actuator therefor as claimed in claim 1 wherein the second piston directly  
35 abuts the top of a valve stem of the poppet valve.

3. An arrangement of an internal combustion engine  
poppet valve and a hydraulic actuator therefor as  
5 claimed in claim 1 or claim 2 wherein the first and  
second pistons directly abut each other when moving  
together.

4. An arrangement of an internal combustion engine  
10 poppet valve and a hydraulic actuator as claimed in  
any one of the preceding claims wherein the first  
chamber is formed in the actuator housing by a first  
diameter drilling and the second chamber is formed in  
the actuator housing by a second diameter drilling.  
15 aligned with the first diameter drilling.

5. An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
any one of the preceding claims wherein:  
20 the passage through the first piston has an  
opening on to the lower surface of the first piston,  
the said opening being at least partially defined by a  
conical abutment surface; and wherein:  
the upper surface of the second piston has a  
25 matching conical abutment surface and the matched  
conical surfaces abut each other whilst the first and  
second pistons move together and by abutment seal the  
passage through the first piston.

30 6. An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
claim 5 wherein the matched conical surfaces together  
act to restrict flow of fluid through the passage in  
the first piston as the second piston comes into  
35 abutment with the first piston and thereby soften  
abutment of the first and second pistons.

7. An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
5 any one of the preceding claims comprising a passage  
through the actuator through which hydraulic fluid  
trapped between one side of first piston and the  
surface of the first chamber as the first piston  
approaches the end stop therefor can be relayed to the  
10 first chamber on the other side of the first piston.

8. An arrangement of an internal combustion engine  
poppet valve and an actuator therefor as claimed in  
any one of the preceding claims wherein the spring  
15 means comprises one or more valve springs acting  
between a collar attached to the poppet valve and a  
surface provided on the engine cylinder head.

20 9. An arrangement of an internal combustion engine  
poppet valve and an actuator therefor substantially as  
hereinbefore described with reference to and as shown  
in the accompanying drawing.



INVESTOR IN PEOPLE

Application No: GB 0223628.9      16      Examiner: John Twin  
Claims searched: 1 to 9      Date of search: 20 March 2003

## Patents Act 1977 : Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1,2,3 at least	JP 2000-282823 A      (Mitsubishi) - see eg WPI abstract accession no.2000-670399; PAJ abstract; figs.1,2
X	1,2,3 at least	JP 2000-045732 A      (Hitachi Zosen) - see eg WPI abstract accession no.2000-218973; PAJ abstract; figs.1,2
X	1,2,3,8 at least	JP 60-085209 A      (Kawasaki) - see eg PAJ abstract; figs.6,7,8

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>6</sup>:

F1B

Worldwide search of patent documents classified in the following areas of the IPC<sup>7</sup>:

F01L

The following online and other databases have been used in the preparation of this search report :

Online: EPODOC, JAPIO, WPI